

REMARKS

Claims 1-31 remain in the application as originally submitted.

The specification is amended to correct a typographical error noted by the Examiner. No other errors were discovered in the specification during the undersigned's review in preparation of this Response. The Examiner's attention to such detail is appreciated.

Claims 1-31 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Watanabe et al. Applicant disagrees and requests reconsideration.

The Examiner is reminded that the application must be reviewed in accordance with 35 U.S.C. §112 as Applicant "regards" its invention. How an Applicant regards its invention is in the manner which Applicant claims the invention. Accordingly, the Examiner needs to consider the obviousness inquiry in the context of Applicant's specific claims, and not in any manner which the Examiner might regard the Applicant's invention apart from the literal claims.

The Examiner asserts that Watanabe et al. discloses a capacitor having a high k capacitor region with three layers of metal oxides of varying stoichiometric potential, and that as such, Watanabe et al. describes various elements and combinations of elements that could be used to arrive at Applicant's various claims. Yet, each of Applicant's claims inherently recites separately what Applicant regards as its invention. And, Applicant's instant

claims are in no way of a breadth which covers all high k metal oxide regions only having some varying stoichiometric potential therein. Rather, each of Applicant's claims are expressly directed to specific attributes which are neither shown nor suggested by Watanabe et al., as further pointed out below.

The Examiner is also reminded that when applying 35 U.S.C. §103, the claimed invention must be considered as a whole, and any applied reference must likewise be considered as a whole. MPEP §2141. Further, in determining the differences between the prior art and the claims, the question under 35 U.S.C. §103 is not whether differences themselves would have been obvious, but whether the claimed invention as a whole would have been obvious. MPEP §2141.02. In addition, a prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. MPEP §2141.02. Also, there must be some suggestion or motivation to modify a reference to arrive at the Applicant's claim, and none is seen in Watanabe et al. MPEP §2143.01.

More specifically, Applicant's independent claim 1 combination includes a high k capacitor dielectric region of metal oxide having multiple different metals bonded with oxygen and having varying stoichiometry across its thickness. Yet, further included in the claim 1 combination is recitation that the layer comprise an inner region, a middle region and an outer region, where the middle region has a different stoichiometry than both the inner and outer regions. This is neither shown nor suggested by Watanabe et al.

While Watanabe et al. might be considered as disclosing inner, middle and outer regions, each of its examples specifically referring to the same provide the middle region to have the same stoichiometry as at least one of the inner and outer regions. (IEC Table 1, and the language pertaining thereto). The other reference in Watanabe et al. with regard to varying stoichiometry is that the proportion of one of the elements varies in one direction in the oxide through the depth of the stacked layers, thereby providing an apparent continual gradient from one elevation of the capacitor dielectric region to the other. (col.4, lns.27-39).

Yet, none of this is what Applicant recites in claim 1. Further, the reference in no way discloses or suggests what Applicant recites in claim 1. To arrive at the modification which the Examiner would make in finding claim 1 obvious requires hindsight reconstruction, which is impermissible. Alternately considered, to arrive at the conclusion of obviousness which the Examiner makes results in a fundamental modification of the reference teachings, with there being no such motivation for such modification in the reference. Applicant is not merely claiming varying stoichiometry in a high k capacitor dielectric region, but rather a specific relationship in the claim 1 combination. As this relationship is not shown nor suggested by Watanabe et al., independent claim 1 should be allowed, and action to that end is requested.

The independent claim 5 combination recites that one or more metals in the subject combination when bonded with oxygen has a first current leakage potential, and another of the metals when bonded with oxygen has a second current leakage potential which is greater than the first current leakage potential. The dielectric region layer comprises at least one portion having a greater concentration of the one metal bonded with oxygen which is more proximate at least one of the first and second electrodes than another portion more proximate a center of the layer. Watanabe et al. says absolutely nothing about one metal when bonded with oxygen as compared to another metal when bonded with oxygen having an effect on the magnitude of current leakage potential. Accordingly, it teaches nothing in this regard, and therefore, certainly does not teach or suggest anything other than positioning some portion having a greater concentration of any metal more proximate at least one of a first and second electrode than another portion more proximate a center of the layer.

Although Watanabe et al. does teach an apparent gradient in stoichiometry difference from one side of the region to another side in stepped stoichiometry differences between middle and outer regions in Table 1, it in no way discloses or suggests the specific relationship which Applicant recites in the independent claim 5 combination. Again, such can only come from hindsight reconstruction, or reading a modification into the reference which the



reference does not motivate. Accordingly, independent claim 5 should be allowed, and action to that end is requested.

The independent claim 12 combination should be allowed essentially for the same reasons argued above with respect to claim 5. In differing from claim 5, claim 12 talks about the absence of one metal in the oxide creating a vacancy, with the lack of vacancy in a second material of the layer having a second current leakage potential which is greater than the first leakage potential created by the vacancy. The claim 12 combination further recites that the high k capacitor dielectric region layer comprises at least one portion having a greater concentration of the first material which is more proximate at least one of the first and second electrodes than another portion more proximate a center of the layer. The arguments provided above regarding claim 5 equally apply to claim 12 with respect to the subject portions as affecting current leakage potential, here by creating a vacancy. Accordingly, independent claim 12 should be allowed, and action to that end is requested.

Applicant's independent claim 18 combination recites that the high k capacitor dielectric region includes a situation where one of the metals when bonded with oxygen has a first dielectric constant, and wherein another of the metals when bonded with oxygen has a second dielectric constant which is less than the first dielectric constant. The combination further includes that the layer comprises at least one portion having a greater concentration of the one metal bonded with oxygen more proximate a center of the layer than

another portion more proximate than either of the first and second electrodes. Under no stretch of the imagination could Watanabe et al. be concluded to render this claim obvious. Watanabe et al. only teaches, in one aspect, a continuous direction gradient from one electrode to another, and in the Table 1 embodiments, a center region which is the same in stoichiometry composition as at least one of the regions adjacent the electrode.

On the other hand, Applicant's claim 18 recites that the subject one portion has a greater concentration of the one metal bonded with oxygen which is more proximate a center of a layer than another portion more proximate either of the first and second electrodes. Again, the only way an obviousness conclusion of Applicant's claim can be arrived at is by hindsight reconstruction, or by modifying the reference in a manner not motivated by it. Accordingly, independent claim 18 should be allowed, and action to that end is requested.

Independent claim 25 should be allowed for essentially the same reasons argued above with respect to independent claim 18. Such also recites, in the combination, a layer comprising at least one portion having a greater concentration of a first material which is more proximate a center of a layer than another portion more proximate either of the first and second electrodes, where the first material and second material relationship is relative to an absence of one metal in the oxide creating a vacancy. For essentially

the same reasons as argued above with respect to claim 18, independent claim 25 should be allowed, and action to that end is requested.

Each of Applicant's dependent claims should be allowed as depending from allowable base claims, and for their own recited features which are neither shown nor suggested in the cited art.

This application is believed to be in immediate condition for allowance, and action to that end is requested. If the Examiner's next anticipated action is to be anything other than a Notice of Allowance, the undersigned respectfully requests a telephone interview prior to issuance of any such subsequent action.

Respectfully submitted,

Dated: 2-19-01

By: 

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application Serial No. MAR 26 2001 09/388,063
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Inventor Vishnu K. Agarwal et al.
Assignee Micron Technology, Inc.
Group Art Unit 2815
Examiner J. Fenty
Attorney's Docket No. MI22-1196
Title: Capacitors Having a Capacitor Dielectric Layer Comprising a Metal Oxide
Having Multiple Different Metals Bonded With Oxygen

MARKED-UP SPECIFICATION PARAGRAPHS
ACCOMPANYING RESPONSE TO DECEMBER 20, 2000 OFFICE ACTION

To: Assistant Commissioner for Patents
Washington, D.C. 20231

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The replacement specification paragraphs incorporate the following amendments the last paragraph on page 6, beginning at line 15 and ending at page 7, line 2. Underlines indicate insertions and ~~strikeouts~~ indicate deletions.

A high k capacitor dielectric region 35 is positioned between first capacitor electrode 24 and second capacitor electrode 26. Capacitor dielectric region ~~34~~ 35 comprises a layer of metal oxide having multiple different metals bonded with oxygen, for example those materials described above. Most preferably and as shown, capacitor dielectric region 35 consists essentially of

such layer, meaning no other layers are received intermediate first electrode 24 and second electrode 26 which meaningfully impact the operation or capacitance of capacitor 32. In accordance with but one aspect of the invention, the metal oxide layer having multiple different metals bonded with oxygen has varying stoichiometry across its thickness. In other words, the stoichiometry in such layer is not substantially constant throughout the layer.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

* * * * *

**Capacitors Having A Capacitor Dielectric Layer
Comprising A Metal Oxide Having Multiple
Different Metals Bonded With Oxygen**

* * * * *

INVENTORS

**Vishnu K. Agarwal
Husam N. Al-Shareef**

ATTORNEY'S DOCKET NO. MI22-1196

1 Capacitors Having A Capacitor Dielectric Layer Comprising A Metal
2 Oxide Having Multiple Different Metals Bonded With Oxygen

3 TECHNICAL FIELD

4 This invention relates to capacitors having a capacitor dielectric
5 layer comprising a metal oxide having multiple different metals bonded
6 with oxygen.

8
9 BACKGROUND OF THE INVENTION

10 As DRAMs increase in memory cell density, there is a continuing
11 challenge to maintain sufficiently high storage capacitance despite
12 decreasing cell area. Additionally, there is a continuing goal to further
13 decrease cell area. One principal way of increasing cell capacitance is
14 through cell structure techniques. Such techniques include
15 three-dimensional cell capacitors, such as trenched or stacked capacitors.
16 Yet as feature size continues to become smaller and smaller,
17 development of improved materials for cell dielectrics as well as the cell
18 structure are important. The feature size of 256Mb DRAMs and
19 beyond will be on the order of 0.25 micron or less, and conventional
20 dielectrics such as SiO_2 and Si_3N_4 might not be suitable because of
21 small dielectric constants.

22 Highly integrated memory devices, such as 256 Mbit DRAMs, are
23 expected to require a very thin dielectric film for the 3-dimensional
24 capacitor of cylindrically stacked or trench structures. To meet this

1 requirement, the capacitor dielectric film thickness will be below 2.5nm
2 of SiO₂ equivalent thickness.

3 Insulating inorganic metal oxide materials (such as ferroelectric
4 materials, perovskite materials and pentoxides) are commonly referred
5 to as "high k" materials due to their high dielectric constants, which
6 make them attractive as dielectric materials in capacitors, for example
- for high density DRAMs and non-volatile memories. In the context of
8 this document, "high k" means a material having a dielectric constant
9 of at least 11. Such materials include tantalum pentoxide, barium
10 strontium titanate, strontium titanate, barium titanate, lead zirconium
11 titanate and strontium bismuth titanate. Using such materials enables
12 the creation of much smaller and simpler capacitor structures for a
13 given stored charge requirement, enabling the packing density dictated
14 by future circuit design.

15 Certain high k dielectric materials have better current leakage
16 characteristics in capacitors than other high k dielectric materials. In
17 some materials, aspects of a high k material which might be modified
18 or tailored to achieve a highest capacitor dielectric constant possible will
19 unfortunately also tend to hurt the leakage characteristics (i.e., increase
20 current leakage). For example, one class of high k capacitor dielectric
21 materials includes metal oxides having multiple different metals bonded
22 with oxygen, such as the barium strontium titanate, lead zirconium
23 titanate, and strontium bismuth titanate referred to above. For example
24 with respect to barium strontium titanate, it is found that increasing

1 titanium concentration as compared to barium and/or strontium results
2 in improved leakage characteristics, but decreases the dielectric constant.
3 Accordingly, capacitance can be increased by increasing the concentration
4 of barium and/or strontium, but unfortunately at the expense of
5 increasing leakage. Further, absence of titanium in the oxide lattice
6 creates a metal vacancy in such multimetal titanates which can increase
7 the dielectric constant, but unfortunately also increases the current
8 leakage.

9 One method of decreasing leakage while maximizing capacitance
10 is to increase the thickness of the dielectric region in the capacitor.
11 Unfortunately, this is not always desirable. Another prior art method
12 of decreasing leakage is described with respect to Fig. 1. There
13 illustrated is a semiconductor wafer fragment 10 comprising a bulk
14 monocrystalline silicon substrate 12. In the context of this document,
15 the term "semiconductor substrate" or "semiconductive substrate" is
16 defined to mean any construction comprising semiconductive material,
17 including, but not limited to, bulk semiconductive materials such as a
18 semiconductive wafer (either alone or in assemblies comprising other
19 materials thereon), and semiconductive material layers (either alone or
20 in assemblies comprising other materials). The term "substrate" refers
21 to any supporting structure, including, but not limited to, the
22 semiconductive substrates described above. A conductive diffusion
23 region 14 is formed within substrate 12. An insulating dielectric
24 layer 16 is formed over substrate 12, and includes an opening 18

1 formed therein to diffusion region 14. Opening 18 is filled with a
2 suitable conductive material 20, for example conductively doped
3 polysilicon or a metal such as tungsten. Barrier, silicide or other layers
4 might also of course be utilized, but are not otherwise described.

5 A capacitor construction 22 is formed outwardly of insulating
6 dielectric layer 16 and in electrical connection with conductive plugging
7 material 20. Such comprises an inner capacitor electrode 24, an outer
8 capacitor electrode 26, and a capacitor dielectric region 25 sandwiched
9 therebetween. Capacitor dielectric region 25 comprises a composite of
10 three layers 26, 27 and 28. Region 27 comprises a layer of metal
11 oxide having multiple different metals bonded with oxygen, such as
12 barium strontium titanate, fabricated to provide a stoichiometry which
13 maximizes the dielectric constant of the material. As referred to above,
14 this unfortunately adversely affects the desired leakage properties of the
15 layer. Accordingly, layers 26 and 28 are received outwardly of layer 27
16 and comprise a material such as Si_3N_4 which exhibits extremely low
17 current leakage. Unfortunately, Si_3N_4 has a considerably lower dielectric
18 constant than the metal oxides having multiple different metals bonded
19 with oxygen. Such adversely reduces the overall dielectric constant, and
20 accordingly the capacitive effect of capacitor dielectric region 25.

SUMMARY

The invention comprises capacitors having a capacitor dielectric layer comprising a metal oxide having multiple different metals bonded with oxygen. In one embodiment, a capacitor includes first and second conductive electrodes having a high k capacitor dielectric region positioned therebetween. The high k capacitor dielectric region includes a layer of metal oxide having multiple different metals bonded with oxygen. The layer has varying stoichiometry across its thickness. The layer includes an inner region, a middle region, and an outer region. The middle region has a different stoichiometry than both the inner and outer regions.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

Fig. 1 is a diagrammatic view of a semiconductor wafer fragment processed in accordance with the prior art, as discussed in the "Background" section above.

Fig. 2 is a diagrammatic sectional view of a semiconductor wafer fragment in accordance with the invention.

Fig. 3 is a diagrammatic view of a chemical vapor deposition chamber utilized in accordance with an aspect of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

The invention is described in one exemplary structural embodiment as depicted by Fig. 2. Like numerals from the Fig. 1 prior art embodiment are utilized where appropriate, with differences being indicated with different numerals. Fig. 2 depicts a wafer fragment 30 comprising a capacitor 32 having first and second electrodes 24 and 26. Example and preferred materials for electrodes 24 and 26 include conductively doped polysilicon, conductively doped hemispherical grain polysilicon, platinum, ruthenium, ruthenium oxides, iridium, iridium oxides, palladium, tungsten, tungsten nitride, tantalum nitride, titanium nitride, titanium oxygen nitride, and the like.

A high k capacitor dielectric region 35 is positioned between first capacitor electrode 24 and second capacitor electrode 26. Capacitor dielectric region ~~34~~³⁵ comprises a layer of metal oxide having multiple different metals bonded with oxygen, for example those materials described above. Most preferably and as shown, capacitor dielectric region 35 consists essentially of such layer, meaning no other layers are received intermediate first electrode 24 and second electrode 26 which meaningfully impact the operation or capacitance of capacitor 32. In accordance with but one aspect of the invention, the metal oxide layer having multiple different metals bonded with oxygen has varying

1 stoichiometry across its thickness. In other words, the stoichiometry in
2 such layer is not substantially constant throughout the layer.

3 In accordance with but one aspect of the invention, consider a
4 high k capacitor dielectric region comprising a layer of metal oxide
5 having multiple different metals bonded with oxygen. One of the metals
6 when bonded with oxygen has a first current leakage potential, while
7 another of the metals when bonded with oxygen has a second current
8 leakage potential which is greater than the first current leakage
9 potential. By way of example only, consider a titanate, such as barium
10 strontium titanate. Titanium is an example of one metal which when
11 bonded with oxygen has a lower current leakage potential than either
12 barium or strontium when bonded with oxygen. In this embodiment, the
13 layer comprises at least one portion having a greater concentration of
14 the one metal bonded with oxygen which is more proximate at least
15 one of the first and second electrodes than another portion which is
16 more proximate a center of the layer.

17 By way of example only, capacitor 32 depicts capacitor dielectric
18 region and layer 35 as comprising an inner region 36, a middle
19 region 38, and an outer region 40. Regions 36 and 40 most preferably
20 constitute portions which are fabricated to have a greater concentration
21 of the one metal, in this example titanium, bonded with oxygen than
22 portion 38. Accordingly, regions 40 and 36 are more proximate at least
23 one of the first and second electrodes than is portion 38 more
24 proximate a center of the layer within capacitor dielectric region 35.

1 Accordingly, the layer or region 35 in this example comprises
2 portions 36 and 40 having a greater concentration of the one metal
3 bonded with oxygen more proximate both the first and second electrodes
4 than the another portion 38 more proximate the center of the layer of
5 capacitor dielectric region 35. Further preferably, region 38 has a
6 greater concentration of the another of the metals (i.e., a greater
7 concentration of one or both of barium and strontium) bonded with
8 oxygen than portions 36 and 40. Further in this preferred example, at
9 least one of portions 36 and 40 (both of such portions as shown)
10 contacts one of the first and second electrodes. As shown, portion 36
11 contacts electrode 24, while portion 40 contacts electrode 26.
12 Regions 36, 38 and 40 can be fabricated to be the same thickness or
13 different relative thicknesses. Further by way of example only,
14 regions 36 and 40 can be fabricated to comprise essentially the same
15 stoichiometry or different stoichiometries. Accordingly, Fig. 2 depicts
16 but one example where the high k capacitor dielectric region includes
17 a layer where a middle region has a different stoichiometry than both
18 inner and outer regions.

19 In an additional or alternate aspect or consideration, consider a
20 high k capacitor dielectric region comprising a layer of metal oxide
21 having multiple different metals bonded with oxygen, where one of the
22 metals when bonded with oxygen produces a first material having a first
23 current leakage potential. Further, absence of the one metal in the
24 oxide creates a vacancy and a second material having a second current

1 leakage potential which is greater than the first current leakage
2 potential. An example would be a multiple metal component titanate,
3 such as barium strontium titanate, where the one metal comprises
4 titanium. In accordance with this implementation, the metal oxide layer
5 comprises at least one portion having a greater concentration of the
6 first material which is more proximate at least one of the first and
7 second electrodes than another portion which is more proximate a
8 center of the layer.

9 Again, Fig. 2 illustrates an exemplary construction, whereby at
10 least one of portions 36 and 40 can be fabricated to have a greater
11 concentration of the first material than another portion 38. Again using
12 barium strontium titanate as an example, titanium constitutes a metal
13 in such material which, when bonded with oxygen, produces greater
14 current leakage potential or resistance than when a vacancy is created
15 in the oxide by absence of the titanium atoms. Accordingly, barium
16 and strontium quantity could essentially be constant throughout the layer
17 of capacitor dielectric region 35, with only the quantity of titanium
18 varying relative to such regions such as described in the preferred
19 example immediately above.

20 In an additional or alternate considered aspect of the invention,
21 consider a high k capacitor dielectric region comprising a layer of metal
22 oxide having multiple different metals bonded with oxygen, where one
23 of the metals when bonded with oxygen has a first dielectric constant.
24 Another of the metals of such layer when bonded with oxygen has a

1 second dielectric constant which is less than the first dielectric constant.
2 The layer comprises at least one portion having a greater concentration
3 of the one metal bonded with oxygen more proximate a center of the
4 layer than another portion more proximate either of the first and
5 second electrodes. By way of example only, barium strontium titanate
6 constitutes one such material. Specifically, barium and strontium in such
7 material constitutes metals which, when bonded with oxygen, produce a
8 first dielectric constant which is greater than when titanium is bonded
9 with oxygen. Accordingly, and again by way of example only and in
10 reference to the above Fig. 2, region 38 constitutes the one portion
11 having a greater concentration of the one metal (i.e., one or both of
12 barium and strontium) bonded with oxygen which is more proximate a
13 center of the layer.

14 In an additional or alternate considered aspect of the invention,
15 consider a high k capacitor dielectric region comprising a layer of metal
16 oxide having multiple different metals bonded with oxygen, where one
17 of the metals when bonded with oxygen produces a first material having
18 a first dielectric constant. Absence of the one metal in the oxide
19 creates a vacancy, and a second material having a second dielectric
20 constant which is less than the first dielectric constant. The metal
21 oxide layer comprises at least one portion having a greater concentration
22 of the first material which is more proximate a center of the layer than
23 another portion which is more proximate either of the first and second
24 electrodes.

1 Again using barium strontium titanate as an example, barium and
2 strontium are example metals whose absence in the lattice when
3 producing vacancies results in a dielectric constant which is less than
4 when present. Accordingly in this example with respect to barium
5 strontium titanate, the one metal comprises at least one of barium and
6 strontium. An exemplary construction encompassing the same is again
- as depicted in Fig. 2.

8 The above-described preferred embodiment was with respect to
9 multiple component titanates wherein both the current leakage potential
10 and dielectric constant aspects of the invention are met in the same
11 material. Alternate materials are also, of course, contemplated whereby
12 perhaps only one of the current leakage potential relationship or the
13 capacitor dielectric constant relationship results, with the invention only
14 being limited by the accompanying claims appropriately interpreted in
15 accordance with the Doctrine of Equivalents.

16 Fig. 3 depicts an exemplary process of depositing a dielectric layer
17 comprising metal oxide having multiple different metals bonded with
18 oxygen in accordance with an aspect of the invention. A chemical
19 vapor deposition chamber 70 has a substrate 72 upon which deposition
20 is desired positioned therein. Exemplary multiple gas inlets 76, 77, 78
21 and 80 are depicted schematically as extending to chamber 70. Fewer
22 or more gas inlets could, of course, be provided. Further, gases could
23 be mixed further upstream of the schematic depicted by Fig. 3, and
24 flowed as mixtures or combinations relative to one or more inlets.

1 Multiple gaseous precursors are fed to the chamber under
2 conditions effective to deposit the dielectric layer having multiple
3 different metals bonded with oxygen on substrate 72. At least some of
4 the precursors comprise different metals of the respective multiple
5 different metals bonded with oxygen, which is deposited in the layer on
6 the substrate. As one example, a process for depositing (Ba,Sr) TiO₃
7 includes utilizing precursors of Ba(DPM)₂, Sr(DPM)₂ and Ti(OC₃H₇)₄,
8 O₂ at 0.5 Torr and 410°C, where "DPM" denotes "dipivaloylmethanato".
9 For example, one of each of these gases could be flowed from the
10 respective inlets 76, 77, 78 and 80. In accordance with one
11 implementation, the flow of at least one of the precursors is varied
12 during the feeding to achieve different concentrations of the different
13 metals bonded with oxygen at different depths in the deposited layer.

14 In compliance with the statute, the invention has been described
15 in language more or less specific as to structural and methodical
16 features. It is to be understood, however, that the invention is not
17 limited to the specific features shown and described, since the means
18 herein disclosed comprise preferred forms of putting the invention into
19 effect. The invention is, therefore, claimed in any of its forms or
20 modifications within the proper scope of the appended claims
21 appropriately interpreted in accordance with the doctrine of equivalents.
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23
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1 CLAIMS:

2 1. A capacitor comprising first and second conductive electrodes
3 having a high k capacitor dielectric region positioned therebetween, the
4 high k capacitor dielectric region comprising a layer of metal oxide
5 having multiple different metals bonded with oxygen, the layer having
6 varying stoichiometry across its thickness, the layer comprising an inner
7 region, a middle region, and an outer region, the middle region having
8 a different stoichiometry than both the inner and outer regions.

9
10 2. The capacitor of claim 1 wherein the inner and outer
11 regions have essentially the same stoichiometry.

12
13 3. The capacitor of claim 1 wherein the metal oxide with
14 multiple different metals bonded with oxygen comprises a ferroelectric
15 material.

16
17 4. The capacitor of claim 1 the capacitor dielectric region
18 consists essentially of the layer.

1 5. A capacitor comprising first and second conductive electrodes
2 having a high k capacitor dielectric region positioned therebetween, the
3 high k capacitor dielectric region comprising a layer of metal oxide
4 having multiple different metals bonded with oxygen, one of the metals
5 when bonded with oxygen having a first current leakage potential,
6 another of the metals when bonded with oxygen having a second current
7 leakage potential which is greater than the first current leakage
8 potential, the layer comprising at least one portion having a greater
9 concentration of the one metal bonded with oxygen which is more
10 proximate at least one of the first and second electrodes than another
11 portion more proximate a center of the layer.

12
13 6. The capacitor of claim 5 wherein the another portion has
14 a greater concentration of the another of the metals bonded with
15 oxygen than the one portion.

16
17 7. The capacitor of claim 5 wherein the layer comprises
18 portions having a greater concentration of the one metal bonded with
19 oxygen more proximate both the first and second electrodes than the
20 another portion more proximate the center of the layer.

21
22 8. The capacitor of claim 5 wherein the at least one portion
23 contacts the one electrode.

1 9. The capacitor of claim 5 wherein the layer comprises
2 portions having a greater concentration of the one metal bonded with
3 oxygen more proximate both the first and second electrodes than the
4 another portion more proximate the center of the layer, said greater
5 concentration portions respectively contacting the first and second
6 electrodes.

8 10. The capacitor of claim 5 wherein the metal oxide with
9 multiple different metals bonded with oxygen comprises a titanate, and
10 the one metal comprises titanium.

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12 11. The capacitor of claim 5 the capacitor dielectric region
13 consists essentially of the layer.
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1 12. A capacitor comprising first and second conductive electrodes
2 having a high-k capacitor dielectric region positioned therebetween, the
3 high-k capacitor dielectric region comprising a layer of metal oxide
4 having multiple different metals bonded with oxygen, one of the metals
5 when bonded with oxygen producing a first material having a first
6 current leakage potential, absence of the one metal in the oxide
- creating a vacancy and a second material having a second current
8 leakage potential which is greater than the first current leakage
9 potential, the layer comprising at least one portion having a greater
10 concentration of the first material which is more proximate at least one
11 of the first and second electrodes than another portion more proximate
12 a center of the layer.

13
14 13. The capacitor of claim 12 wherein the layer comprises
15 portions having a greater concentration of the first material more
16 proximate both the first and second electrodes than the another portion
17 more proximate a center of the layer.

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19 14. The capacitor of claim 12 wherein the at least one portion
20 contacts the one electrode.
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1 15. The capacitor of claim 12 wherein the layer comprises
2 portions having a greater concentration of the first material more
3 proximate both the first and second electrodes than the another portion
4 more proximate a center of the layer, said greater concentration
5 portions respectively contacting the first and second electrodes.

6
7 16. The capacitor of claim 12 wherein the metal oxide with
8 multiple different metals bonded with oxygen comprises a titanate, and
9 the one metal comprises titanium.

10
11 17. The capacitor of claim 12 the capacitor dielectric region
12 consists essentially of the layer.

13
14 18. A capacitor comprising first and second conductive electrodes
15 having a high k capacitor dielectric region positioned therebetween, the
16 high k capacitor dielectric region comprising a layer of metal oxide
17 having multiple different metals bonded with oxygen, one of the metals
18 when bonded with oxygen having a first dielectric constant, another of
19 the metals when bonded with oxygen having a second dielectric constant
20 which is less than the first dielectric constant, the layer comprising at
21 least one portion having a greater concentration of the one metal
22 bonded with oxygen more proximate a center of the layer than another
23 portion more proximate either of the first and second electrodes.

1 19. The capacitor of claim 18 wherein the another portion
2 contacts one of the first and second electrodes.
3

4 20. The capacitor of claim 18 wherein the another portion has
5 a greater concentration of the another of the metals bonded with
6 oxygen than the one portion.
7

8 21. The capacitor of claim 18 wherein the layer comprises
9 portions having a greater concentration of the another metal bonded
10 with oxygen more proximate both the first and second electrodes than
11 the one portion more proximate the center of the layer, said greater
12 concentration portions respectively contacting the first and second
13 electrodes.
14

15 22. The capacitor of claim 18 the capacitor dielectric region
16 consists essentially of the layer.
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18 23. The capacitor of claim 18 wherein the metal oxide with
19 multiple different metals bonded with oxygen comprises a titanate, and
20 the another metal comprises titanium.
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1 24. The capacitor of claim 18 wherein the metal oxide with
2 multiple different metals bonded with oxygen comprises barium strontium
3 titanate, and the one metal comprises at least one of barium and
4 strontium.

5
6 25. A capacitor comprising first and second conductive electrodes
7 having a high k capacitor dielectric region positioned therebetween, the
8 high k capacitor dielectric region comprising a layer of metal oxide
9 having multiple different metals bonded with oxygen, one of the metals
10 when bonded with oxygen producing a first material having a first
11 dielectric constant, absence of the one metal in the oxide creating a
12 vacancy and a second material having a second dielectric constant which
13 is less than the first dielectric constant, the layer comprising at least
14 one portion having a greater concentration of the first material which
15 is more proximate a center of the layer than another portion more
16 proximate either of the first and second electrodes.

17
18 26. The capacitor of claim 25 wherein the layer comprises
19 portions having a greater concentration of the first material more
20 proximate both the first and second electrodes than the another portion
21 more proximate a center of the layer.

22
23 27. The capacitor of claim 25 wherein the another portion
24 contacts the one electrode.

1 28. The capacitor of claim 25 wherein the layer comprises
2 portions having a greater concentration of the another material more
3 proximate both the first and second electrodes than the one portion
4 more proximate a center of the layer, said greater concentration
5 portions respectively contacting the first and second electrodes.

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7 29. The capacitor of claim 25 the capacitor dielectric region
8 consists essentially of the layer.

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10 30. The capacitor of claim 25 wherein the metal oxide with
11 multiple different metals bonded with oxygen comprises a titanate.

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13 31. The capacitor of claim 25 wherein the metal oxide with
14 multiple different metals bonded with oxygen comprises barium strontium
15 titanate, and the one metal comprises at least one of barium and
16 strontium.

1 ABSTRACT OF THE DISCLOSURE

2 The invention comprises capacitors having a capacitor dielectric
3 layer comprising a metal oxide having multiple different metals bonded
4 with oxygen. In one embodiment, a capacitor includes first and second
5 conductive electrodes having a high k capacitor dielectric region
6 positioned therebetween. The high k capacitor dielectric region includes
7 a layer of metal oxide having multiple different metals bonded with
8 oxygen. The layer has varying stoichiometry across its thickness. The
9 layer includes an inner region, a middle region, and an outer region.
10 The middle region has a different stoichiometry than both the inner and
11 outer regions.
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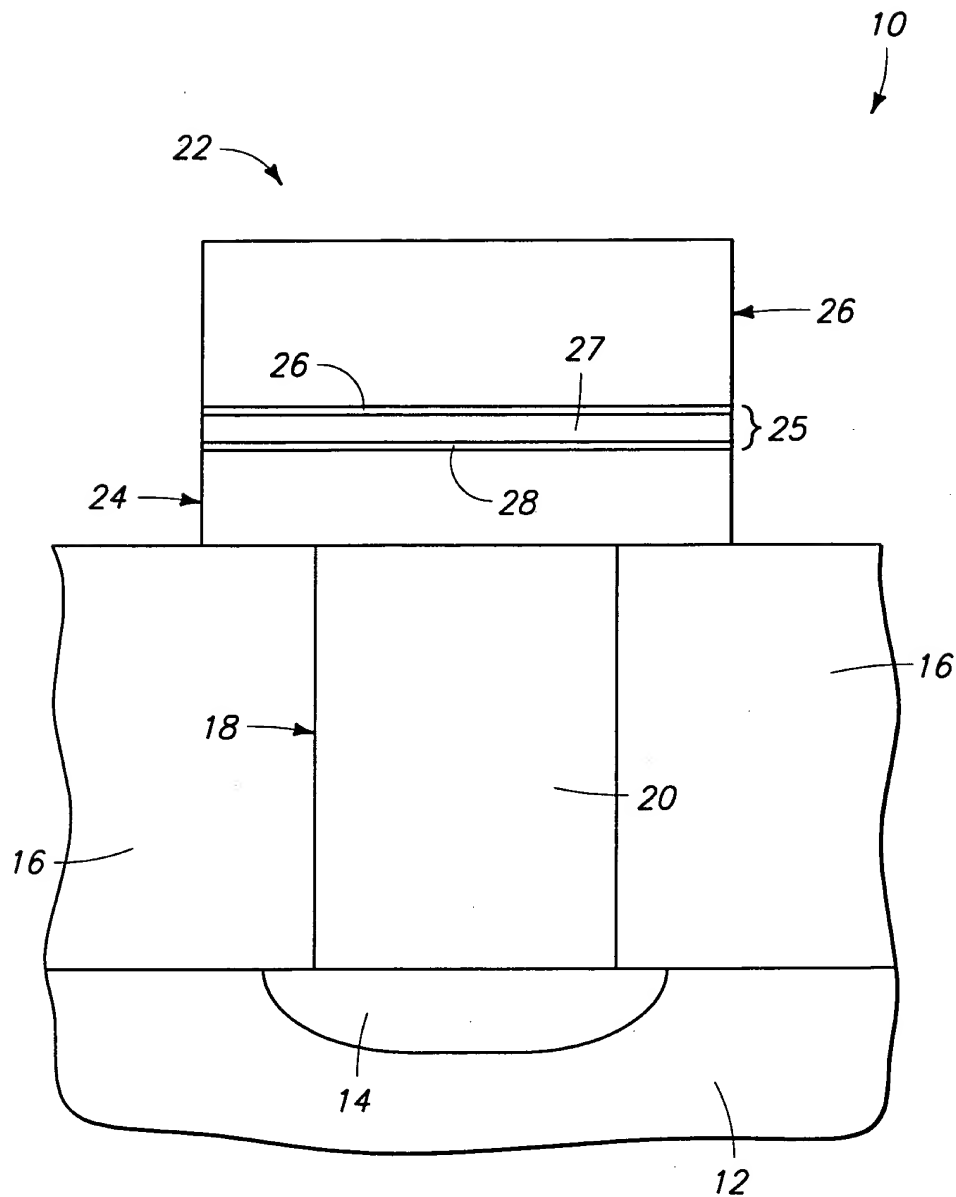
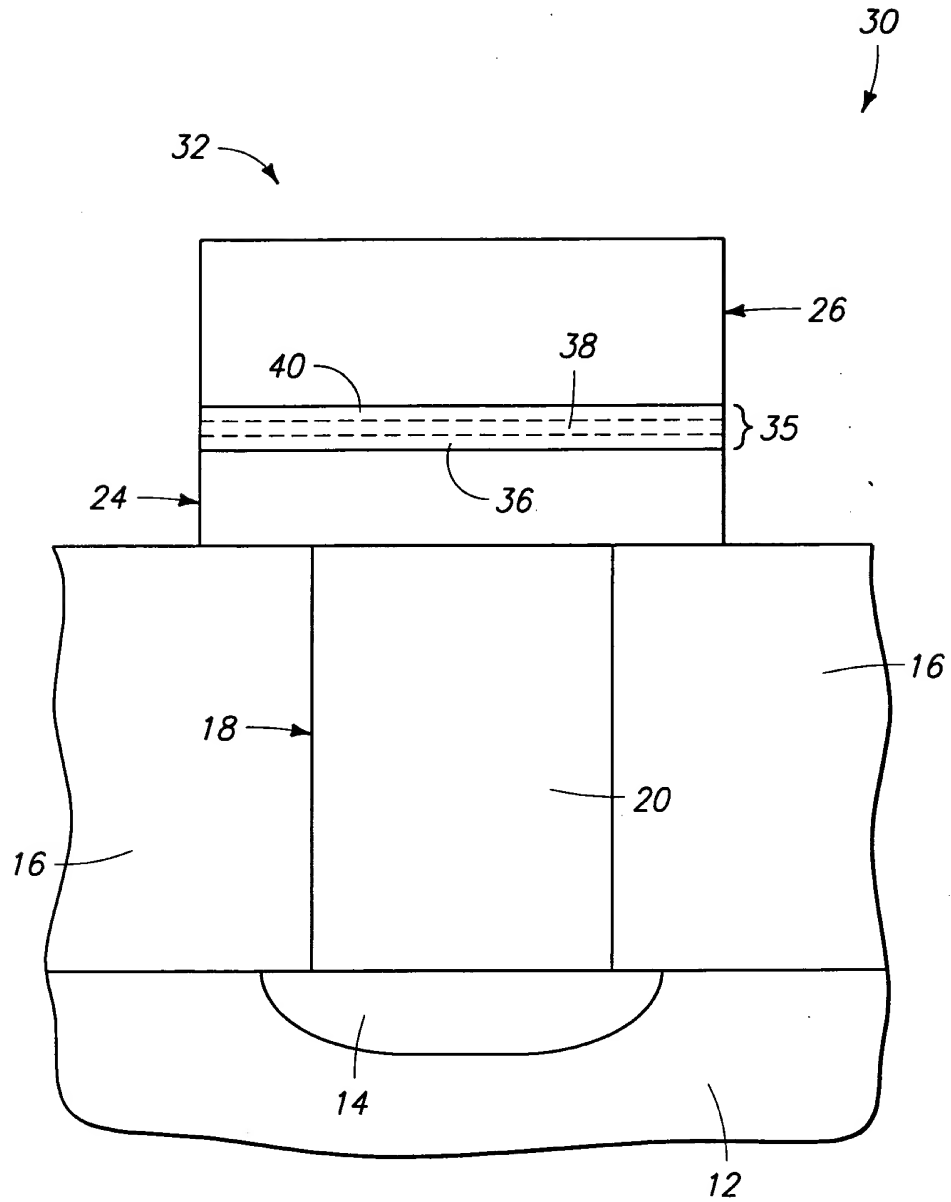
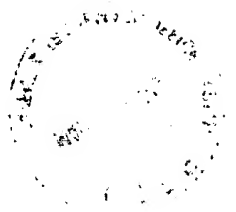


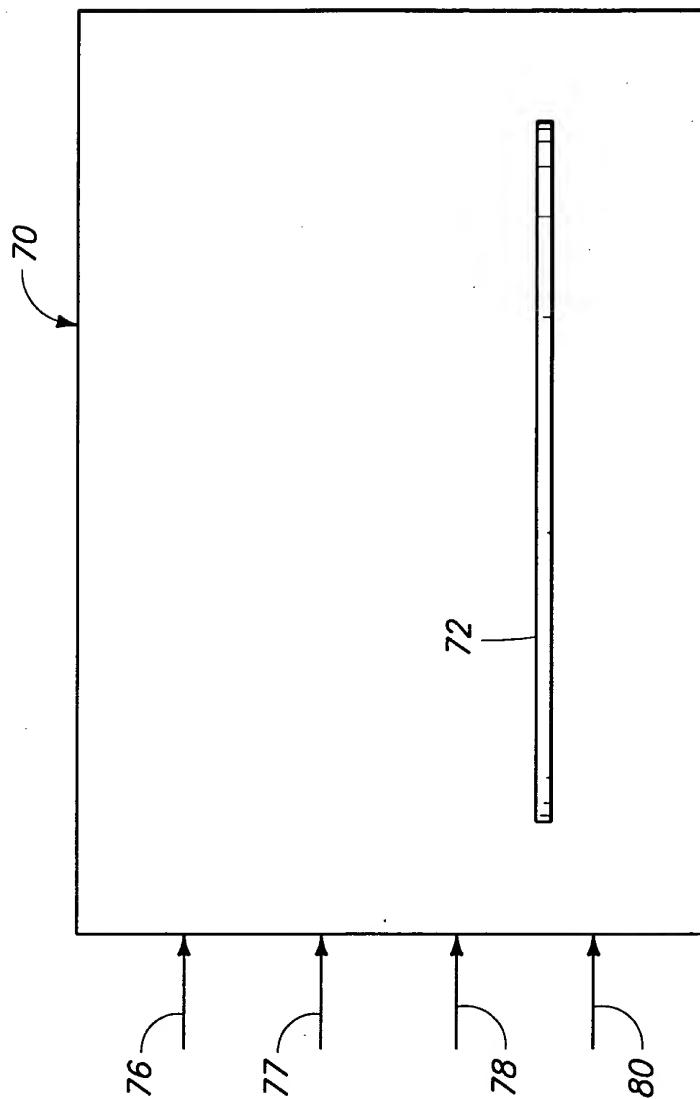
FIG. 1
PRIOR ART





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LEON II